Breeding Leguminous Vegetable Crops

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INTRODUCTION

Leguminous vegetables have been cultivated for more than 6,000 years in different parts of the world. Legumes for human consumption constitute about 5% of the cultivated crops. World production of selected vegetable legumes are given in Table 1.

Table 1. Area and production of selected vegetable legumes in specific region and the world.

Vegetable	Country / Region	Area ha x 1000	Production t x 1000
Green Peas	World	802	4,699
	Asia	89	144
Green Beans	World	391	2,527
	Asia	102	636
Dry Peas	World	8,428	11,361
	Southeast Asia	27	22
Dry Beans	World	25,959	14,637
	Southeast Asia	1,437	1,082
Soybeans	World	52,600	96,000
	Asia	7,500	10,000

In countries like India where majority of the population is vegetarians leguminous vegetables serve as the major source of protein in the diet. In developing third world countries, especially for the poor people, the major protein source in the diet is vegetable legumes. Most of the leguminous vegetables are rich in phosphorous, calcium, iron and a number of essential vitamins. Crops like soybean, groundnut, and Bambara groundnut are also rich in fats which are essential for the absorption of vitamin A by our system. Although leguminous vegetables are deficient in some of the sulphur containing amino acids when consumed with cereals they are well compensated. In selected instances the leaves, tender shoots and roots are harvested and used as vegetables. The whole seed of some of the legumes are called *Gram*. Seeds of legumes without seed coat and cotyledons split into half is commonly called as *Pulses* in India. Similarly the split pigeon pea, *Cicer arietinum* L. is referred to as *Dal* in India and Pakistan. According to Vavilov all the main centers of origin of cultivated plants have contributed cultivated legumes of today.

Legumes are rather unique compared to other vegetables in that they can obtain atmospheric nitrogen free through their symbiotic association with the nitrogen fixing bacteria, *Rhizobium* or *Bradyrhizobium* in legumes root nodules. The nitrogen fixed in the

root nodules are not only available to the plant but also they enrich the soil, in varying amounts, when the plants complete their life cycle.

Many leguminous vegetable plants contain toxic substances like trypsin inhibitor (soybean, *Glycine max* (L) Merrill), rotenone (yambean, *Pachyrhizus erosus* L.,) and cyanogenic glucoside (hyacinth bean, *Lab lab niger* L., and *Lathyrus sativus* L.). There are diverse ways by which the toxic effects of these vegetables can be eliminated and they are rendered safe for human consumption.

Depending upon the country some of the legumes are included in the field crops section, others are included in the horticultural crops section, while still others are included in the oilseeds crop section. However, in many of the monographs dealing with vegetable legumes published in different countries almost all these crops are treated as vegetable crops.

In addition to being used as fresh pod, immature seed and mature dry seed, majority of these vegetables are also canned and frozen for the market. Some of the legume seeds are sprouted and they are popular in many Asian countries. Many legumes are also processed and used.

In international trade leguminous vegetables play an important role. Dry seeds, canned and frozen foods and processed food products from leguminous vegetables enter into international market and they are important commodities in foreign exchange consideration both from the point of view of drain and earnings

BOTANY

Legumes are dicotyledonous annuals or perennials. There are about 480 genera and more than 12,000 species in the family *Leguminosae* (commonly called the Pea family). As a group they contain at least 28 different vegetable crops belonging to 18 genera. Almost all the vegetable crops belong to the sub-family *Papilionaceae.*

Leaves of legumes are usually alternate, and mostly compound, pinnate, trifoliolate or digitate. The flowers are perfect (stamens and ovaries occur in the same flower). The flowers have characteristic papilionaceous corolla (Fig. 1). The stamens are arranged in two bundles. Nine stamens are united together to form a bundle or staminal column and one stamen is free. The stamens are commonly referred to as diadelphous. The style is filamentous and ends in a capitate stigma. The flower structure of common bean is shown in Fig. 2. Majority of the legumes are self pollinated. In some cases certain amount of cross pollination also occurs. Bees are the main agents for cross pollination.

When the seeds germinate, in some legumes, the cotyledons remain inside the soil due to limited elongation of the hypocotyl. Such germination is referred to as *hypogeal* germination. Example : Peas, *Pisum sativum* L. In other instances, as in the case of soybean (*Glycine max* L. (Merr.)), and common bean (*Phaseolus vulgaris* L.) the cotyledons are pushed above the soil surface by the rapid elongation and growth of the hypocotyl. Such germination is called *epigeal* germination.

A list of leguminous vegetables commonly grown in South and Southeast Asia are given in Table 2.

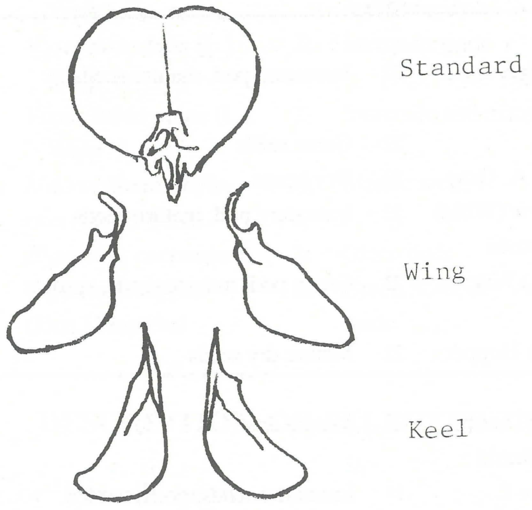

Fig. 1. Typical Papilionaceous corolla

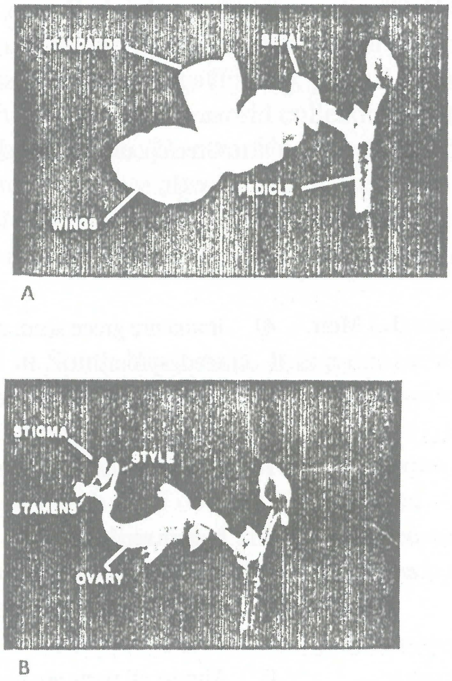

Fig. 2. Flower structure of the common bean at the time of anthesis. A - Side view of open flower; B - Flower with calyx and corolla removed.

Table 2. List of leguminous vegetables.

Crop	Botanical name	Chromosome No.	Edible part	Adapatation
Beans				
Common, Snap, String,	*Phaseolus vulgaris* L.	22	Immature pod, mature seeds	Temp. and Tropic.
Limabean	*P. lunatus* L.	22	Green seeds	Warm season
Tepary bean	*P. acutifolius* A. Gray	22	Dry beans	Dry areas
Adzuki bean	*Vigna angularis* (Willd) Ohwi & Ohashi	22	Immature pod, mature seeds	Warm season
Mungbean, green-gram	*V. radiata* (L.) Wilczck	22	Green pod, mature seeds, sprouts	Warm season
Blackgram, Urd bean	*V. mungo* (L.) Hepper	22	Mature dry seeds	Warm season, dry tropics.
Rice bean	*V. umbellata* (Thunb) Ohwi and Ohashi	22	Mature dry	Warm season
Peas	*Pisum sativum* L.	14	Immature seeds, pods, tender leaves	Cool, humid sea-son
Peanut, Groundnut	*Arachis hypogaea* L.	40	Mature seed, tender shoots and leaves	Tropics and sub-tropics, warm temp
Swordbean	*Canavalia gladiata* (Jacq.) D. C.	22, 44, 46	Young pods, and beans	Tropics
Pigeon pea, redgram	*Cajanus cajan* L. Mill sp.	22	Young green pods, seeds mature seeds	Warm season
Chickpea, Bengalgram	*Cicer arietinum* L.	16	Green pods, tender shoots, dried seeds	Cool, dry
Clusterbean, guar	*Cyamopsis te-tragonoloba* (L.) Taub.	14	Young tender	Dry tropics
Soybean	*Glycine max* (L.) Merr.	40	Immature green seed; mature dry seed, sprouts	Tropics to 52^{o}N
Hyacinth bean, lablab bean	*Lablab purpureus* (L.)	22,	Young pods, tender bean, dried seeds	Dry season
Grass pea, Chickling pea	*Lathyrus sativus* L.	14	Seeds, leaves used as herbs	Cool season
Lentil	*Lens culinaris* Medikus	14	Mature seed	Winter crop
Yam bean	*Pachyrhizus erosus* Urban	22	Succulent roots	Hot, wet tropics perennial
Potato bean	*P. tuberosus* spreng	22	Tubers	Perennial
Winged bean,	*Psophocarpus te-tragonolobus* D. C.	18	Almost all parts are used	Tropical Asia
Fenugreek	*Trigonella foenum-graecum* L.	?	Mature seeds	Winter

Faba bean, broad bean, Horse bean, Windsor bean	*Vicia* faba L.	12	Green beans, dry seeds	Temp. Cool season
Cowpea, Catjang	*Vigna unguiculata* (L.) Walp	22	Immature pods, young shoots dry beans	Trop. Africa
Yardlong bean, Asparagus bean	*V. sesquipedalis* (L.) Walp	22	Immature pods	Warm season
Bambara groundnut	*Vigna subterranea* (L.) Walp	22	Immature and mature seeds	Tropical Africa
Horsegram	*Macrotyloma uniflorum* (Lam.) Verdc	20, 22	Mature seeds	Dry tropics
Runner bean	*Phaseolus coccineus* L.	22	Green pods	Temperate
Moth bean	*Vigna aconitifolia* (Jacq.) Marechal	22	Green pods, dry whole or split seeds	Tropical

DESCRIPTION OF SELECTED LEGUMES

1. Snap, String or French bean

Phaseolus vulgaris likely originated from Central America. It is commonly associated with corn and squash culture in the tropical Latin American countries.

It is an annual, twining vine or bush with alternate trifoliolate leaves (Fig. 3). Indeterminate cultivars are 2-3m tall while the determinate cultivars are 20-60cm tall. Stem angular or nearly cylindrical; Inflorescence axillary or terminal racemes, with white, pink, lilac or purple flowers; stamens diadelphous (9+1); ovary laterally compressed with 4-12 (usually 7) ovules; style upturned and spiralled with collar of fine hair below the stigma. Stigma ellipsoid, glandular, directed adaxially (Fig. 2); germination is epigeal.

CIAT in Cali, Colombia has classified the world collection into following four main types by growth habit : 1). dwarf determinate, 2). dwarf indeterminate,3). prostrate indeterminate and 4). climbing indeterminate. Beans are also classified according to use as follows : snap or string beans (for tender fresh pods); green shell beans (green shelled condition, normally bush and climbing varieties); and dry-shell or field beans (mature dry seeds);

2. Peas

Peas probably originated in South-West Asia. It is a cool season crop in the subtropics and also grown at higher altitudes in the tropics.

Botanically it is an annual climbing herbaceous plant (Fig. 4); leaves are pinnate with 2-3 pairs of leaflets and a terminal tendril, at base with 2 leaf-like stipules. Flowers are axillary racemes with 1-2 flowers; ovary with 4-15 ovules. Germination is hypogeal. It is a long day plant. The flowers are strictly self-pollinated. Classification primarily by the type of seeds, either round or wrinkled. Round seeds are for fresh green peas or mature dry seed while wrinkled are used for canning or freezing while it is immature.

3. Mungbean

India or the Indo-Burmese region is the origin of mungbean. In South-Asia it is one of the major leguminous vegetable crop. In South-East Asia it is one of the three main legumes.

It is an erect or semi erect annual (Fig.5); true trifoliolate leaves are alternate and the leaflets are ovate or deltoid. Flowers are large and the inflorescence is axillary racemes. Pods spreading, pendent, cylindrical, straight, pubescent or glabrous. Seeds are green or yellow, occasionally brown or blackish, with dull or glossy lustre. Germination is epigeal.

4. Vegetable Soybean (*Edamame*)

Soybean originated as a demesticate in the eastern half of northern China around the 11th century BC. Soybeans were introduced from China to USA, Japan, Korea and South and South-East Asian countries at different times.

Usually an erect, bushy, annual, herbaceous plant (Fig. 6), leaves are alternate, trifoliolate, glabrous to pubescent; leaflets ovate to lanceolate, entire, base rounded, apex acute to obtuse; inflorescence axillary or terminal racemes with 3-30 flowers; flowers small, purple or white; stamen 10, diadelphous, style curved with capitate stigma; pods dehiscent; seeds usually globose, yellow, green, brown, black or mottled; germination is epigeal. Large yellow or green seeded varieties with gray hilum color is preferred for use as vegetable soybeans. Based on latitudinal adaptation soybean cultivars in the U.S.A. and Canada have been classified into 13 maturity groups (MG). The MG 000, 00, and 0 are early and adapted to extreme North latitudes while MG IX and X are late and adapted to tropical latitudes. However, this MG system breaks down in the tropical and subtropical latitudes.

Fig. 3. *Phaseolus vulgaris* L. 1 - fruiting branch; 2 - inflorescence; 3 - seeds.

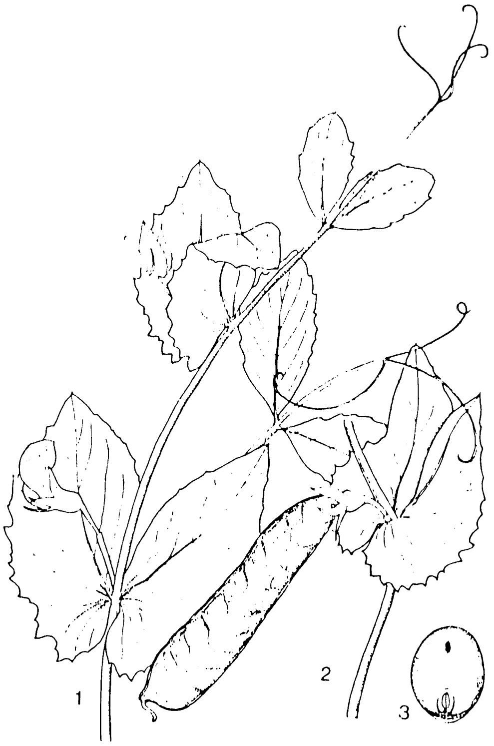

Fig. 4. *Pisum sativum* L. 1 - branch with flower; 2 - branch with fruit; 3 - seeds.

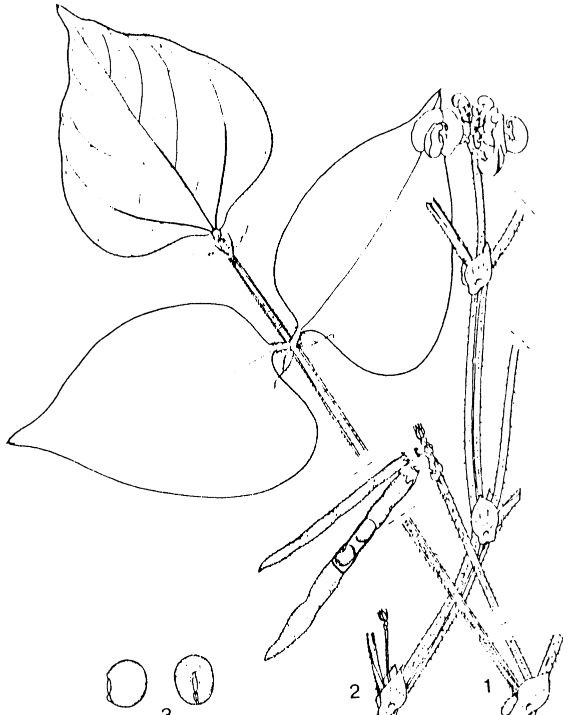

Fig. 5. *Vigna radiata* (L.) Wilczek. 1 - fruiting branch; 2 - flowering branch; 3 - seeds.

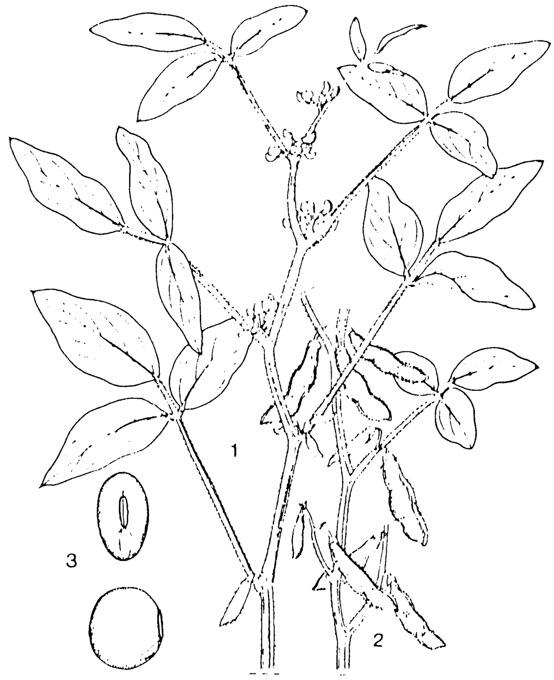

Fig. 6. *Glycine max* (L.) Merr. 1 - flowering branch; 2 - fruiting branch; 3 - seeds.

CONTROLLED HYBRIDIZATION PROCEDURES

1. Snap bean

Artificial hybridization of field-grown plants are largely unsuccessful. Majority of the hybridizations are done in plants grown in greenhouses or in protected conditions. *P. vulgaris* is a short day plant. Snap bean is highly self-pollinated and it can be safely assumed that no outcrossing occurs in greenhouse grown plants.

Pollen grain dehiscence and self-pollination occur in the late bud stage, usually at night, with pollen tube growth commencing almost immediately.

Fine tipped, curved or straight, forceps a small bottle of alcohol for rinsing the forceps, cellophane tape and dispenser, small tags on strings, coin envelopes about 65 x 110 mm and a magnifying lens are the tools needed for pollination.

The stigma is receptive at least 2 days prior to and 1 day after anthesis. Plump buds, with color, will open the following day, are chosen as female parent. Already self-pollinated stigma is swollen, dried and light green in color. Before pollination stigma is white and sticky.

Emasculation and cross pollination can be done throughout the day. Cross pollination can be made either with or without emasculation. The standard petal is opened by inserting the forceps into the suture and pushing from side to side. Next the winged petals are removed. The coiled keel petal must be removed to expose the anthers . Make a small incision on the top of the keels and grasp the upper lip and peel it up and back. Once when the keels are

removed stigma and anthers are exposed. Often the keel breaks and it is necessary to remove enough of the keel. Then remove the 10 stamens without rupturing the anther sacs. Make sure to count the stamens removed. Dip the forceps in alcohol periodically to prevent contamination.

Crosses made prior to 11:00 hrs and after 15:30 hrs are more successful than other times. Pollinations are made either by rubbing the pollinated stigma or by hooking on to the stigma of the emasculated female parent. In the hooking method the pollinated stigma of the male parent is removed from the male and rubbed against the female stigma and left in the female flower by hooking it through the style of the latter near the stigmatic surface. Clamping method is used without emasculation. Pollen laden stigma of the male is hooked behind the protruding stigma of the female.

To prevent desiccation of freshly pollinated stigma, the standard petal is closed gently following pollination and bud may be enclosed with cellophane tape. After pollination, place a tag around the pedical of the female flower.

A success rate of 30 to 40% is common with rubbing method. The success rate with hooking method is 70 to 90%.

2. Peas

A pair of forceps with sharp tips, 95% ethanol for killing undesired pollen, tags to identify crosses and a pencil to record the cross on the tag are the only equipments needed for artificial hybridization.

Strong, vigorously growing young plants which began to flower offer the best for successful artificial hybridization. Success rate with older plants are very poor. Cooler times with high relative humidity occurring during morning is preferrable for field hybridization. In the greenhouse and in controlled growth cabinets hybridization can be done throughout the day. Pea flowers are large and easy to handle for hybridization (Fig. 7 A4). The flower bud for crossing will have petals extending beyond the sepals (Fig. 7 A2) in which anthers are yet to dehisce. Younger flower buds are more difficult to emasculate and are easily damaged (Fig 7 A1) and may set a fewer seeds. Remove all flowers other than the ones to be emasculated and pollinated from that peduncle to reduce competition for nutrients.

In emasculation the flower the first step is to carefully tear away the tip of the sepal with the forceps from in front of the keel. By moving the standard petal back and the wings sideways insert the sharp tip of the forceps and slit the keel (Fig. 7B). Spread the keel apart and held them down with finger and thumb. Remove the 10 anthers by grasping the filament with the forceps and carefully pulling (Fig. 7C). Count the anthers to make sure that all 10 anthers have been removed.

An alternative emasculation procedure is to roll the standard and wing petals back and hold them with thumb and index finger. Then grasp the keel and tear off its upper part along with the anthers. If the single free anther remains, it is removed with the finger nail or point of forceps or pencil.

Pollen can be collected at any time of the day from freshly dehisced anthers. Pollen dehiscence occurs when the petals begin to open. Good pollen will be rich moist yellow. Untreated pollen could be stored for 6 days after dehiscence and still useful for fertilization. Vacuum drying and storage at 25°C extended pollen viability for 1 year. Use a tooth pick, tip of the forceps, a cotton swab, or a stigma to collect and transfer the heavy sticky pollen (Fig. 7D). The receptive surface is the elliptical stigmatic tip of the sytle, not the hairs on the

concave side. Tag the pollinated flower to identify the cross (Fig. 7E). Identify the male and female parents, date of pollination and name of the pollinator. Use a water proof pen.

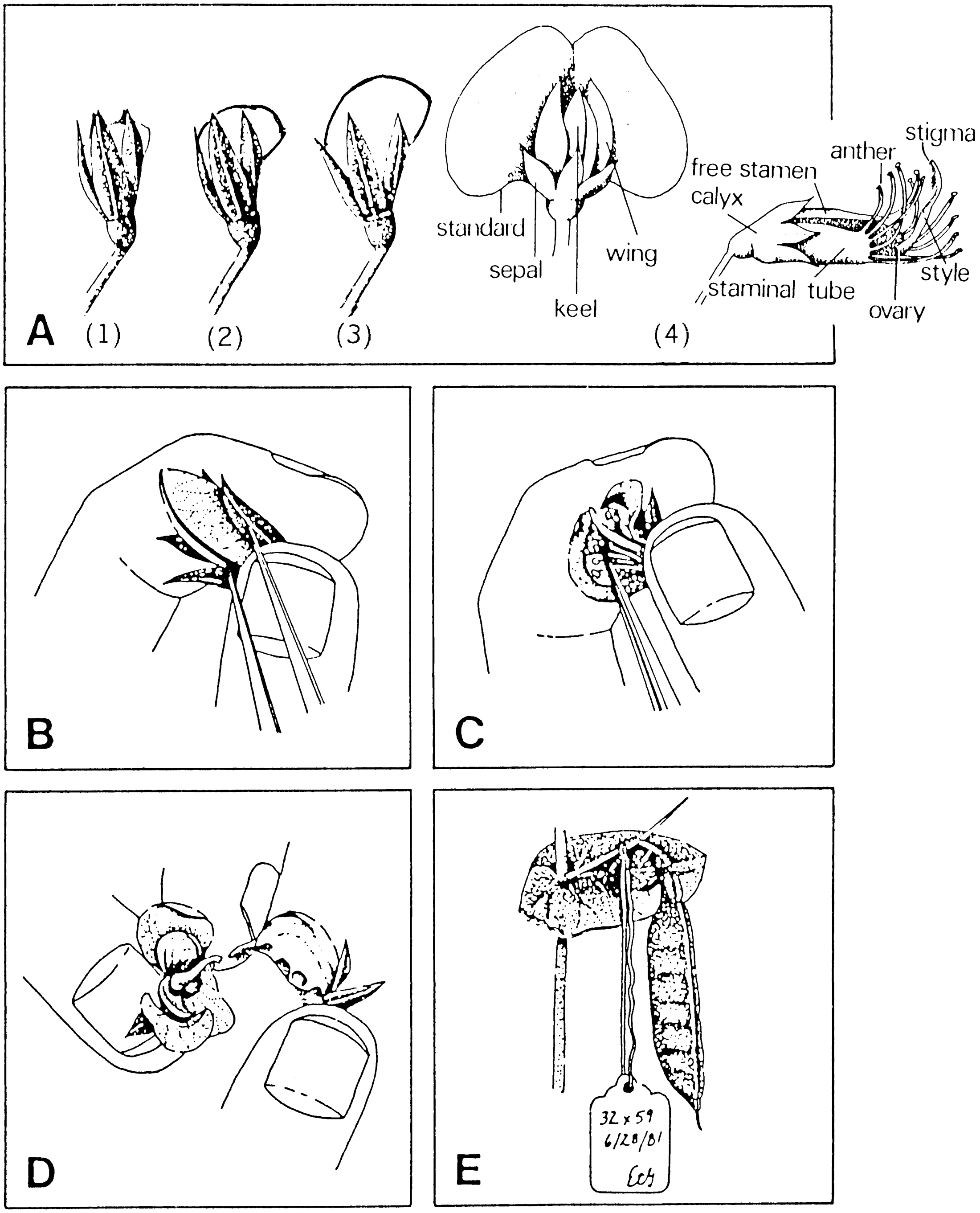

Fig. 7. Pea flower - Stages in pollination. A1 - not ready for pollination; A2 - just ready for pollination; A3 - already pollinated; A4 - open flower; B - opening the keel; C - removing anthers; D - using pollen laden style to transfer pollen to emasculated flower; E - developing pod with tag.

for several weeks in a desiccator at 3°C. Pollinated flowers are identified with tags as described for other crops. An experienced breeder can hybridize 20 to 50 flowers per hour in indeterminate and determinate cultivars respectively with a success rate of 50%. Steps in emasculation and pollination are shown in Fig. 8.

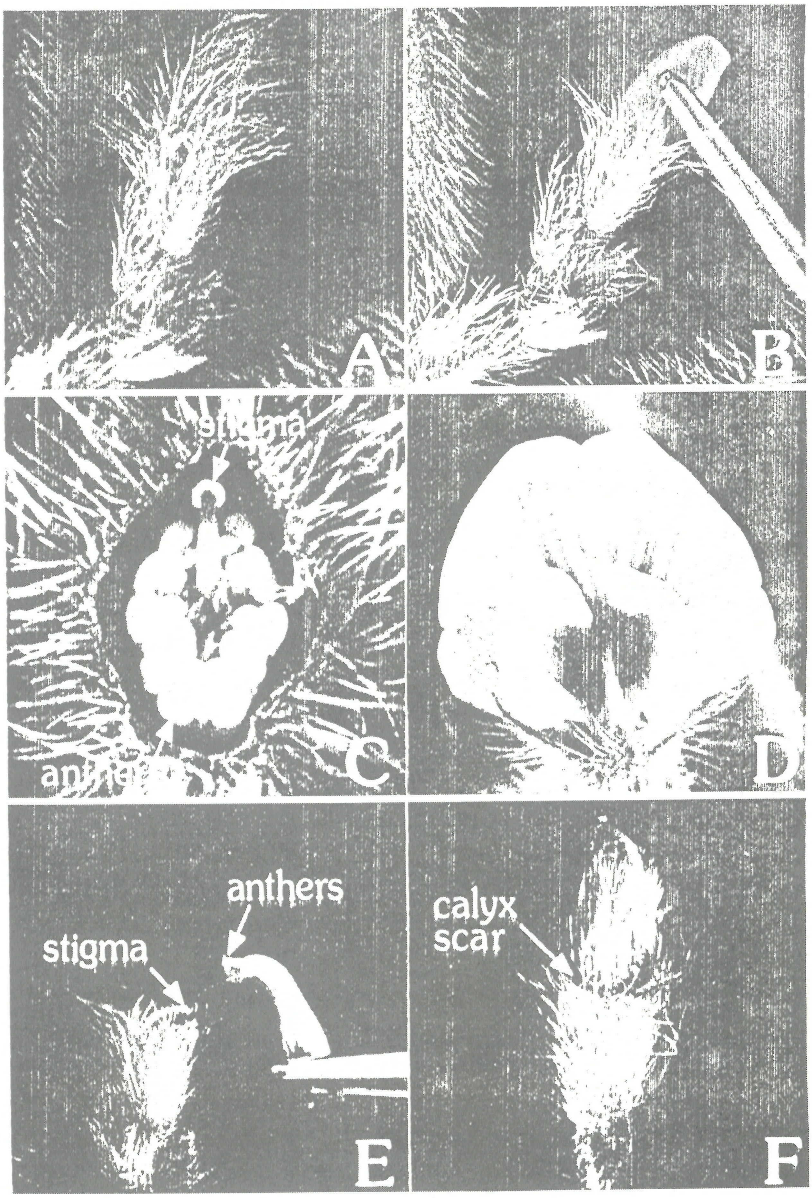

Fig. 8. Preparation and pollination of a soybean flower. (A) Flower at the stage for preparation and pollination, (B) removal of the corolla from the female flower after the calyx has been removed, (C) ring of 10 anthers and the stigma, (D) flower with pollen available, (E) pollination of the stigma, and (F) a pod 7 days after pollination with the calyx scar differentiating it from self-pollinated pods. (Photographs A, B, D, E, and F by C. J. Deutsch and P. A. Krumhardt, Iowa State Univ., Ames, Iowa; photograph C by G. L. Berkdy, Ohio Agric. Res. and Devel. Ctr., Wooster, Ohio).

3. Mungbean

Self pollination of mungbean flowers begins from 21:00 - 22:00 hours and completed around midnight. The following morning flowers begin to open and remain in full bloom until shortly before noon. By mid to late afternoon flowers are fully closed. Cleistogamy is common. Self-pollination is the rule. However, usually 0.4% cross pollination by bees have been reported. At AVRDC upto 13% natural cross pollination was observed in some genotypes.

For emasculation, the standard petal is pushed to one side and the wing petal outward with a dissecting needle. The keel petal and anthers are removed with forceps avoiding injury to the stigma. From the male parent a stigma is selected that is covered with fresh pollen from dehisced anthers and the pollen laden stigma is brushed across the stigma of the emasculated flower.The wing and standard petals are returned into place after pollination. Emasculation in the evening and pollination in the following morning gives maximum seed set. Success rate varies from 20% to 60% pod set.

Recently a new technique has been developed. The tip of the bud is opened with fine tipped forceps to expose the style and stigma, and the anthers are slowly dislodged from the filaments. After pollinating the emasculated bud, a cellaphane tag is placed over the opening to seal the bud. Using this method emasculation and pollination can be done in one minute. The success rate is 60%.

4. Vegetable Soybean

The soybean is a short day plant. Genetic variability for sensitivity to photoperiod exists. Temperatures below 21°C and above 32°C can inhibit floral initiation and seed set. Artificial hybridization is most successful between 26°C and 32°C. High humidity improves the success of artificial hybridization. Success with growth chamber or greenhouse hybridizations are limited in some cultivars (especially in temperate countries).

Soybean flowers are self pollinated on the day when petals open. Natural outcrossing through honeybees is about 1%. The stigma is receptive a day prior to and 2 days following anthesis. Prior to anthesis the anthers are below the stigma. As anthesis approaches the filaments elongate rapidly and surround the stigma. The anthers dehisce on the day of anthesis. Within 10 hours after the pollen grains fall on the stigma the pollen tubes reach the ovary and fertilization is effected.

The equipment needed are a pair of forceps with fine tips and a smooth interior surface. Plastic or paper tags to identify the pollinated flowers. A 2.5x magnifiers mounted on a headband is useful to see the flower parts clearly. Petri dishes or paper envelopes are used to collect male flowers. Desiccators with calcium chloride crystals are used to dry male flower and obtain adequate pollen in some environments.

The buds with corolla just visible are chosen for emasculation. Generally for each node no more than two buds are chosen for pollination. All other flowers are removed. First the five calyx are removed with the forceps. By grasping just above the calyx scar all the petals can be removed by gently lifting and wiggling movements. Sometimes one can remove all the anthers along with the petals. Otherwise remove all 10 stamens by counting them.

Emasculation is unnecessary if proper bud is chosen for pollination. But emasculation is recommended. Anthers are difficult to remove if the flower is immature. If the stigma is surrounded by the anthers then pollination has already occurred.

The female flower after emasculation is immediately pollinated by taking the stamens from the male plant and smearing on the stigma of the female flower. Flowers can be stored

GENERAL PRINCIPLES OF BREEDING SELF POLLINATED CROPS

The major goal of any plant breeder is to develop improved varieties that is profitable to the farmers and acceptable to the consumers and processors.

Populations developed from a single genotype or a mixture of genotypes are commonly referred to as strains, experimental strains, or breeding lines. Plant breeder evaluates thousands of strains every year. True to type and identity are essential qualifications of a variety (also called cultivar). In self-fertilized crop plants, since the individuals in a population tend to be homozygous, the range of purity within a variety depends upon its origin and genetic stability. When a variety is developed from a single genotype which is true breeding, in a self fertilized crop, they are called pure line.

In a crop which is predominantly self-pollinated the plants in the population will be largely homozygous. This assumption is due to the face, a). gene pairs that are homozygous (AA or aa) will stay as homozygous with selfing, b). gene pairs heterozygous will segregate to produce equal proportions of homozygous and heterozygous progeny.

By selfing heterozygosity is reduced by one-half with each successive selfing (Table 3). As can be seen from Table 3 with each generation of selfing the proportion of heterozygous individuals decreases while that proportion of homozygous true breeding individual increases. It requires about five to eight generations of selfing to reach an acceptable practical level of homozygosity. At such stage, homozygous individuals are isolated and multiplied to produce a pure line population. Variability in pure lines may arise due to natural cross pollination or mutation. However, the progenies of such variants again quickly segregate giving rise to homozygous genotype.

Table 3. In a self pollinated crop the proportion of heterozygous individuals decreases and homozygous individuals increases with each successive generation of selfing.

Generation	Percentage of		
	Homozygous dominant	Heterozygous	Homozygous recessive
F_1	0	100	0
F_2	25	50	25
F_3	37.5	25	37.5
F_4	43.75	12.5	43.75
F_5	46.875	6.25	46.875
F_6	48.4375	3.125	48.4375
F_7	49.21875	1.5625	49.21875

1. Breeding methods

The common methods that are widely used are (a). introduction, (b). selection and (c). hybridization and selection. Direct introduction of promising varieties that are pure is the first step. In cases when there is a mixture in an introduced variety or locally available varieties then selection and pureline development is practiced. But when desirable characters are distributed in different varieties which need to be combined then hybridization and selection is

resorted to. In breeding self pollinated crops, enclosing flowers in bags to ensure selfing as in cross pollinated crops is unnecessary.

Two methods of selection are practiced in breeding self pollinated crops. They are (a). mass selection and (b). single plant or pureline selection.

A. Mass Selection

Selection of phenotypically similar plants and compositing the seeds without progeny testing is called mass selection. Plants of the population may not necessarily be homozygous. Therefore, phenotypic selection may be necessary in subsequent generation if purity is desired. However, the genetic variation within a mass selected population may offer some buffering against differing environmental variation.

B. Pureline or Single-Plant Selection

The progeny of a single homozygous self-pollinated genotype is called a pureline. It is more uniform than mass selected line. It is assumed that the selected genotype is homozygous for all gene loci which is invariably not true. New genotype are not created by pureline. Purelines may become impure due to a). mechanical mixtures with others, b). natural outcrossing and c). mutations.

C. Hybridization and Selection

In self-pollinated crops the following three major methods of selection in segregation population are practiced following hybridization : a). pedigree selection, b). bulk population and c). single seed descent.

In pedigree method desirable single plants are selected in the F_2 generation. The progenies of selected plant are further reselected until genetic purity is obained (Fig. 9). In bulk-population method selection is delayed until F_5 or F_6 when practical homozygosity has reached. When F_2 plants and their progenies are advanced in succeeding generations by single seeds until genetic purity is obtained, then it is called single seed descent method (Fig. 10).

A number of modifications of pedigree and bulk methods are used by different plant breeders. A combination of the two methods are also attempted. In addition, recurrent selection procedure is also used in recent years. A group of elite parents are chosen. They are intermated. The progeny of the intermated population is harvested individually and evaluated in a replicated test. The best lines are selected and intermated for second cycle of testing.

Instead of testing and selecting at later generations, when the genotypes are fairly homozygous, early generation testing is also practiced with varying levels of success in different crops.

In recent years the objective in hybridization is to create as much variability as possible in the source population to increase the combination of favourable alleles specifically for quantitative traits and ensure maximum gene recombination. It is also directed to break the tight linkage blocks.

Back crosses are used to transfer some qualitatively inherited characters from a genotype to a popular cultivar. Modified backcrosses involve the use of more than one recurrent parent.

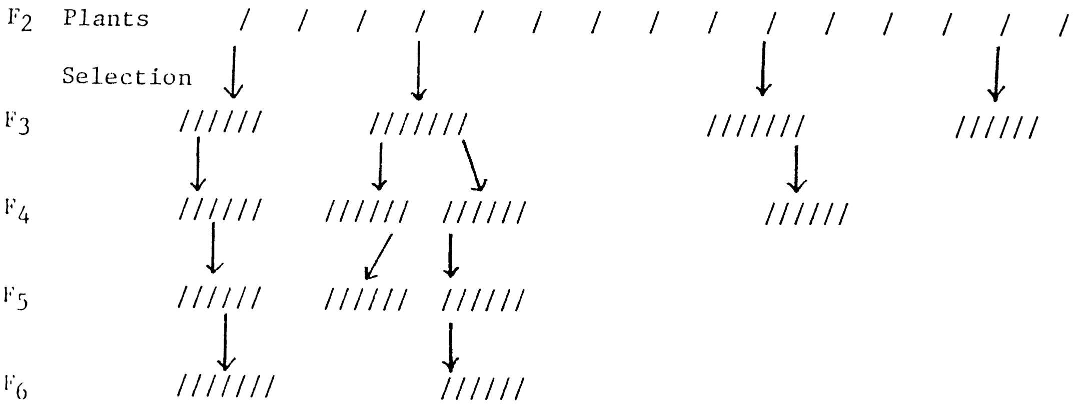

Fig. 9. Pedigree method. Best rows and best plants are selected in each generation.

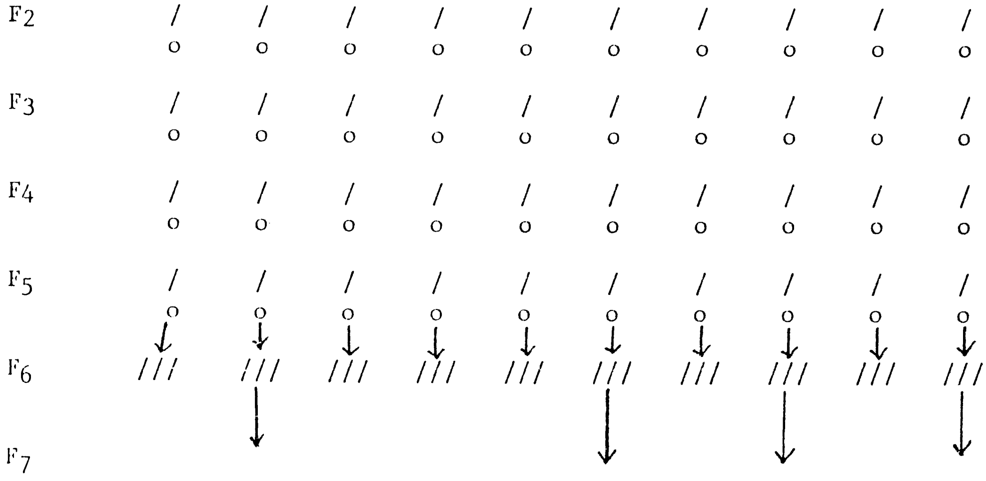

Fig. 10. SSD method. One seed is harvested from each F_2 plant and advanced; in F_3 again one seed is harvested and advanced. It is continued until F_5. Then select best family.

BREEDING OBJECTIVES FOR SPECIFIC CROPS

1. Snap bean

Collection of germplasm to enrich the genetic diversity, and an understanding of the inheritance of the available genetic diversity are two non-specific breeding objectives. The germplasm committee of the Bean Improvement Cooperative has compiled a bean gene catalog.

The objectives of the bean breeding program should take into consideration the farmer, the seedsman, the processer and the consumer. Good seed quality, concentrated pod maturity, strong upright narrow growth habit, resistance to various disease and insects, tolerance to environmental stresses are some of the most important objectives.

In areas or seasons with high rainfall pole types are preferred. In other seasons there is an interest in developing bush types. As in other crops high yield is one of the important objectives. Fresh market quality and sloughing free cultivars for canning industry; and short periods for whole pod processing are other important objectives.

2. Peas

The major breeding objectives are yield, improvement of standing capacity of the crop, regional adaptability, suitable plant type, lodging and shattering resistance, disease and insect resistance, environmental stress resistance and quality for different purposes.

Specific varieties are developed with round and wrinkled seeds; fresh edible pods; shelling green peas for fresh market or for canning and freezing; for mature seed and for tender shoots (specifically in Taiwan).

In the case of edible podded peas elimination of strings from the pods, dwarf vine bearing double pods, thick crisp pod wall and resistant to prevalent diseases such as root rot, powdery mildew and virus diseases are the major objectives.

Development of altered foliage types, as shown in Fig. 11 especially semi-leafless tendril types is gaining interest since they have the advantage of improved standing ability, color uniformity of berry, and pest control.

3. Mungbean

Mungbean is a very short duration crop. The current goal of the program is to develop stable, high yielding mungbean lines with resistance to diseases and pests, synchronized maturity and improved quality suitable for the tropics and subtropics. The specific objectives vary from country to country. Some of the common objectives are as follows :

a. to develop stable high yielding (> 2.0 t/ha), early and uniformly maturing, large seeded cultivars;
b. to incorporate reduced sensitivity to photoperiod and temperature variation;
c. to add resistance to Cercospora leaf spot (CLS), powdery mildew (PM), viruses, beanfly, bruchids and pod borer;
d. to develop tolerance to lodging, seed shattering, field weathering, drought and other environmental stresses;

Some countries prefer dull seed coat (e.g. Taiwan, Korea) while others prefer shiny seed coat (India, Pakistan). Most countries prefer large seeded types while Korea prefers small seeded varieties. In the Philippines yellow seeded varieties are also preferred over green seed in some regions.

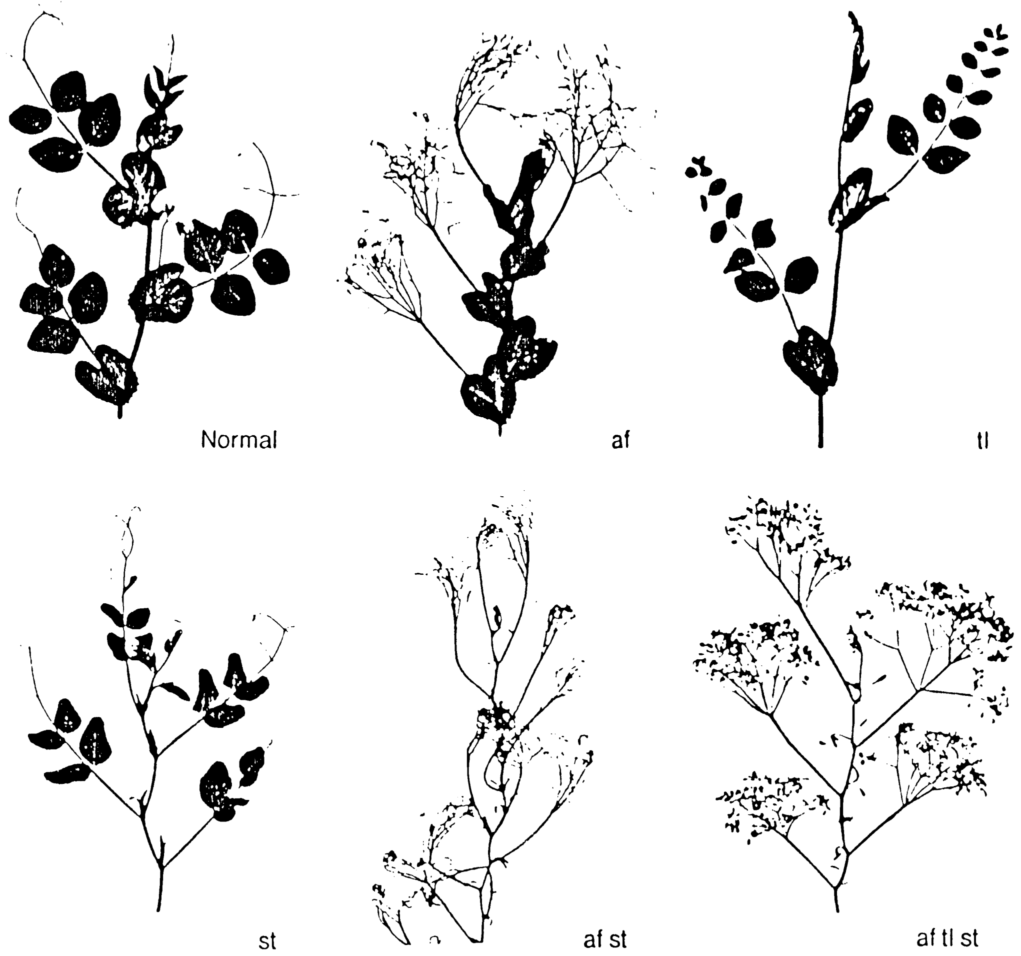

Fig. 11. Some pea foliage types. Normal has the genotype *Af /Af, Tl /Tl, St /St*. The homozygous recessive gene(s) responsible for each different type is (are) shown below each type.

4. Vegetable Soybean

There is no universally accepted definition of vegetable soybeans. In general, the taste, flavor and seed size are the primary consideration for vegetable soybean. In breeding vegetable soybeans for the Japanese market the pods and seeds should be large (the dry weight of 100 seeds should be 30 g or more; and 500 g packet of frozen pods should contain 175 pods or less); pods should have two or more seeds; one seeded, malformed, yellow, or damaged pods are unacceptable; the pod and seed color should be bright green; gray pubescence on the pod and light brown or gray hilum is required; good flavor and texture are needed; slightly sweet taste is preferrable while oily taste is undesirable; short cooking time is desired; when once the crop reaches the maturity stage that is right for harvesting the time taken to reach the next growth stage (yellowing of pods) should be longer (good 'holding capacity'). Pods should preferrably remain green for a longer period under high temperature after reaching the harvest stage to enable the processers to harvest in phased stages.

SELECTION TECHNIQUES AND EVALUATION

1. Snap Bean

In selecting for strong upright plant, commonly referred as "Tender crop plant type" "weak kneed types" should be discarded.

PI 165426 has small leaf size and was reported to have resistance to rhizoctonia root rot and root-knot nematode and was the base for the development of several bush type cultivars.

For a review of breeding for disease resistance see the references by Schwartz and Galvez (1980); Silbernagel and Zaumeyer (1973); and Zaumeyer and Meiners (1975). Note that these references can be located in the reference by Silbernagel (1986).

Some of the recently identified sources of resistance to major diseases are listed in Table 4.

Table 4. Sources of resistance to diseases.

Disease	Pathogen	Resistant sources	Mechanism (Genes)
Bean Common Mosaic Virus	BCMV	Most US snap beans	I resistance : bc-1^2, bc-2^2, bc-3
Curly top	virus	Apollo, Blue Mountain, Gold Crop, Wonder Green	Epistatic dominant
Rust	*Uromyces Phaseoli* (Ruben) Wint.	PR-190, 8BP-3, Resisto BPSR-130	
Anthracnose	*Colletotrichum* sp.	8BP-3	ARE
Root rots	*Fusarium solani*	—	Quantitative
	Pythium	RRR-36,RRR-46	
	Aphanomyces euteiches f. sp. *phaseoli* Phend & Hag	RRR-36, RRR-46	
Halo blight	*Pseudomonas syringae* pv *Phaseolicola* (Burk) Comb. nov.	Noorinbee, RH-13 Nebraska, HB-76-1	

Since there are several market preferences for which beans are produced, specific characters that are acceptable to all needs are unavailable for use as selection criteria.

Initial emphasis in early generation should be screening for resistance to locally prevailing diseases. The remnant from the segregating population should be evaluated for horticultural and agronomic characteristics using the data sheet (Table 5). Since the diseases and pod characteristics may vary widely between locations and seasons it is essential to screen and evaluate the segregating population in different seasons and different production locations. The undesirable types and susceptible plants should be ruthlessly discarded.

Simply inherited traits could be recovered and stabilised at F_2 or F_3 generation itself. Selection for more complex quantitatively inherited characters with low heritability should be postponed to F_5-F_8 generations. During early generations for such quantitative traits, such as root rot resistance low selection pressure should be applied and highly sensitive individuals can be discarded.

Table 5. Snap bean data sheet.

Name ______________ Snap Bean Cultivar Trial Date Sown ______________

Institute ______________ Data Sheet Expt. Site ______________

Address ______________ (Elevation) (______________)

Plot	Entry	Rep.	Total	Harvest sequence							MPN	MPY	TY	MY	PL			PW			Diseases/pests		Remarks
No.		No.	Stand		1st	2nd	3rd	4th	5th	Total		(g)	(t/ha)	(t/ha)	1	2	Ave.	1	2	Ave.	Rust	Insect damage	
				DH																			
				PN																			
				TPW(g)																			
				MPW(g)																			
				DH																			
				PN																			
				TPW(g)																			
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				DH																			
				PN																			
				TPW(g)																			
				MPW(g)																			

DH=Date harvested; PN=No. of pods harvested; TPW=Weight of pods harvested; MPW=Weight of marketable pods after removing defected pods;

MPN=Mean pod no. per plant=Total PN/Total stand; MPY=Mean pod yield per plant=Total TPW / Total stand; TY=Total yield= $\frac{\text{Total TPW(g)}}{\text{Plot size (m}^2\text{) X 100}}$;

MY=Marketable yield= $\frac{\text{Total TPW(g)}}{\text{Plot size (m}^2\text{) X 100}}$; PL and PW=Pod length and pod width, respectively. Measure length and width of randomly chosen ten pods at optimum harvest and take their mean; Diseases/pests damage : Score the severety with scales 0=no damage to 9=most serious damage.

Screening for virus resistance is done both in the field and in the greenhouse. Segregating population is kept at 24-48 hr in the dark prior to mechanical inoculation. At 24°-28°C virus symptoms are expressed in 10-14 days. Symptomless plants should be inoculated again regardless whether it is in the field or greenhouse to confirm the resistance.

Similar screening techniques are available for bacterial and fungal diseases.

For root rot a rating index has been developed. The disease index is calculated as follows

$$\frac{100[0(\text{No. at }0) + 1(\text{No. at }1) + 2(\text{No. at }2) + 3(\text{No. at }3) + 4(\text{No. at }4) + 5(\text{No. at }5)]}{(\text{Total plants}) \times (\text{No. of disease categories} - 1)}$$

where, the sum of the products (number of plants in each disease category) x (numerical value of that category) is multiplied by 100. That product is divided by the product of the total number of plants times one less than the number of disease categories used. This system allows for comparisons among researchers who use different disease severity ratings (e.g. 0-4, 1-5, 1-9) by putting all results on a 0 to 100 basis.

What to Save? Category 0 is immune, 1 is highly resistant, 2 is moderately resistant, 3 is moderately susceptible, 4 is very susceptible, and 5 is highly susceptible. Plants with a rating of 0 or 1 are usually considered resistant enough to save for seed production.

A schematic representation of breeding procedure is given in Fig. 12.

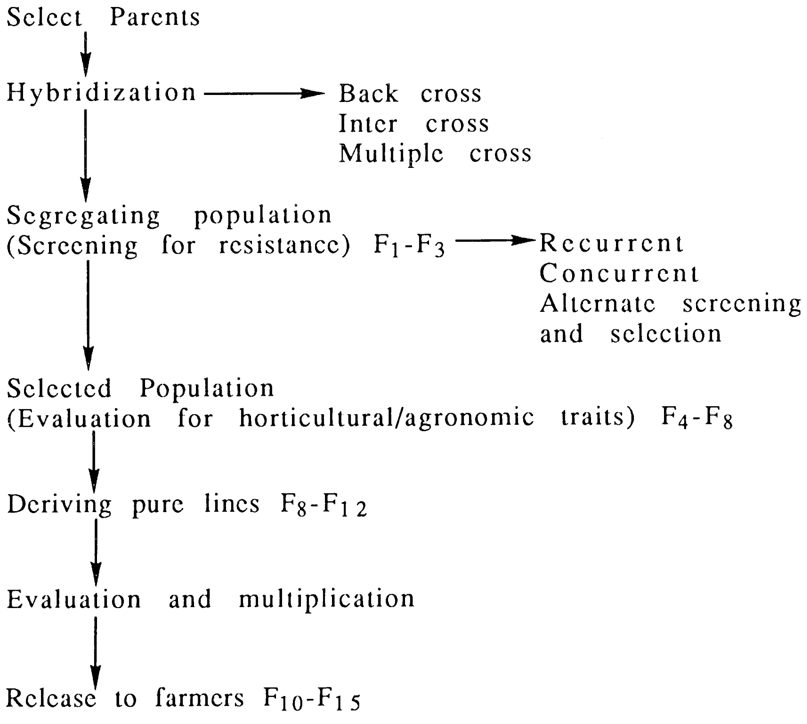

Fig. 12. Flow chart of bean breeding program.

Normally it takes about 9 to 10 years to develop a new improved variety. For yield evaluation 3 to 6m long single row plot with 3 to 6 replications are used. Sequential planting and different harvest dates are used for evaluation. At least two season data are needed to promote the lines for extensive testing. A processed quality evaluation form is given in Fig. 13.

Variety | Sieve Size | Date Harvested ___________

Location | Canned-frozen Sample | Date Evaluated ___________

Style Pack : Whole Cut

Quality Evaluation :

Appearance :	Attractive	5	4	3	2	1	Poor
Liquor :	Clear	5	4	3	2	1	Discolored
Pod Color :	Green	5	4	3	2	1	Gray
Suture Color :	Green	5	4	3	2	1	Brown
Defects :	Low	5	4	3	2	1	High
Flavor :	Good	5	4	3	2	1	Poor
Texture:	Firm	5	4	3	2	1	Mushy
String :	No String	5	4	3	2	1	Stringy
Sloughing :	None	5	4	3	2	1	Excessive
Carpels :	No Slippage	5	4	3	2	1	Excessive

Quality Rating. Total [ ]

Comments :

10 seed length	m m	
Seed Range	min-max	
Deseeded Pods Wgt.	0.00g	
Seed Wgt.	0.00g	
% Seed		Seed Grade
Fiber Basket #		
After Drying Wgt.	0.0000g	
Before Drying Wgt.	0.0000g	
% Fiber-Blender Method	(diff in g)	
Fiber Grade		

Fig. 13. Processed quality evaluation form.

Yield, maturity and sieve size data are useless unless they are related to quality. The quality traits include flavor, texture, carpel separation, skin sloughing, interlocular cavitation, internal tissue breakdown and color.

2. Peas

Peas are one of the first crops studied by Gregor Johann Mendel who proposed the genetic basis of heredity. Extensive genetic studies have unravelled the inheritance of most of the qualitative characters, their linkage relationships and the chromosome association. A genetic map has also been prepared.

Round seed is dominant over wrinkled (gene R) and it is easy to select. All garden, canning or freezing cultivars carry green cotyledons (gene i). It is usually necessary to chip away a portion of the seed coat to expose the cotyledon when scoring for cotyledon color.

Greenhouse or field disease nurseries are established to screen for common root rot caused by *A. euteiches*. Roots of seedlings are inoculated with a mycelial - zoospore suspension of the fungus. The seedlings are then replanted in growth medium and held at about 25°C. Two weeks after inoculation the lines are rated.

Screening for different races of *Fusarium* is usually done in the greenhouse. Resistance to powdery mildew screening is done in the field.

Virus disease resistance screening is done by artificially inoculating the plants.

The pedigree method and a combination of bulk or pedigree and SSD methods are used by judiciously planting inbreeding generations in the greenhouse and field in the three different generations (Table 6).

Table 6. Pedigree-Bulk or Pedigree-Single-Seed Descent Breeding Scheme.

Operation	Location	Season
Make cross	Greenhouse	Fall
Grow F_1 plants	Greenhouse	Spring
Grow F_2 plants and select desired types	Field	Summer
Grow F_3 plants to advance generations	Greenhouse	Fall
Grow F_4 plants to advance generations	Greenhouse	Spring
Grow F_5 plants and select desired types	Field	Summer
Disease test F_6 plants	Greenhouse	Fall
Increase seed of desired F_6 plants	Greenhouse	Spring
Grow single-plant selections on trellises	Field	Summer

A method used to transfer a recessive gene for disease resistance to a successful cultivar is shown in Fig. 14.

3. Mungbean

Pedigree selection is commonly practiced in segregating generations following hybridization. Most mungbean cultivars have been developed from two parent crosses. For example, 'PAGASA' 1 is from the cross "CES 87" x 'ML-5; "VC 1560 Sel. A" is derived from a three parent cross 'BPI Glabrous 3' x ('CES 44' x 'ML-3').

A "plant type" concept was proposed that focussed on short, compact plants; high harvest-index; reduced photoperiod sensitivity, early maturity and more determinate growth habit.

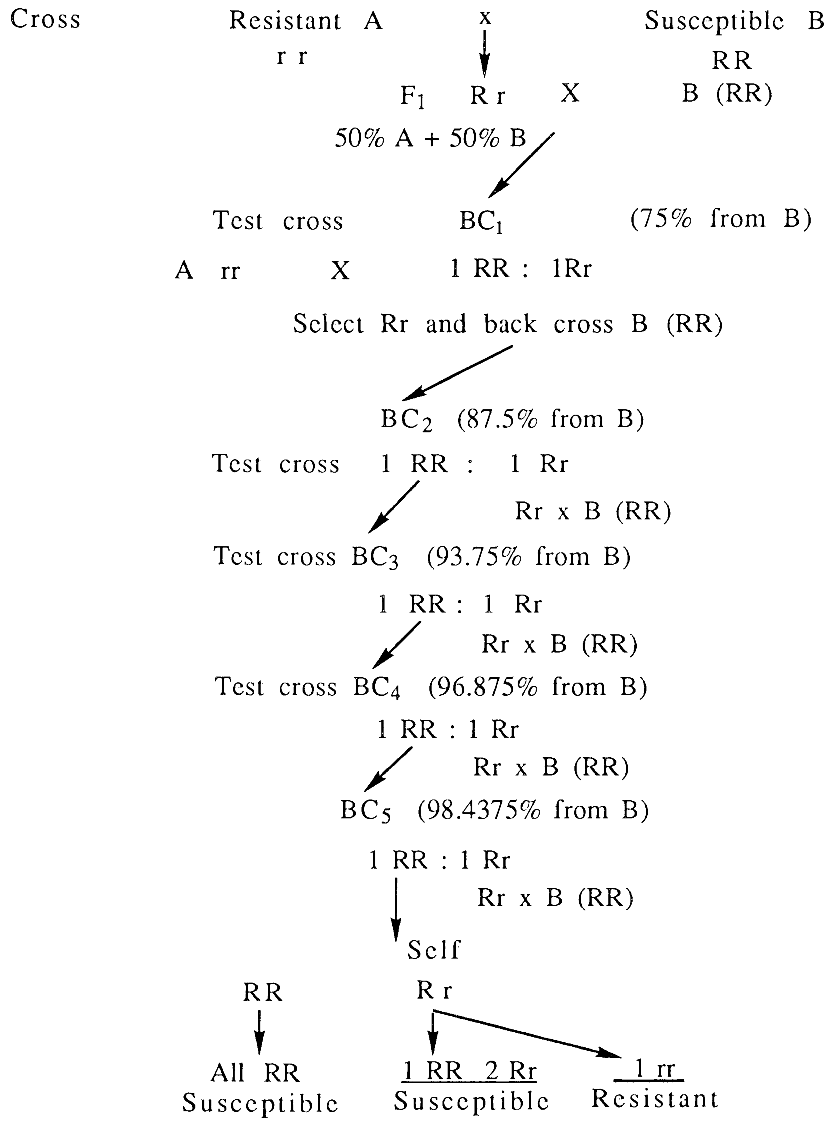

Fig. 14. Transfer of a recessive gene for disease resistance via simultaneous backcrossing and test crossing.

Mungbeans are selected on the basis of productivity, evenness in maturity, total growth, adaptability to seasons and resistance to diseases. A gene for yellow seed coat was identified and included in the selection program.

At AVRDC, powdery mildew is common in spring and autumn season crops when the weather is cool and dry. During summer, when the weather is hot and humid, *Cercospora*, leaf spot is widely prevalent. The segregating generations are subjected alternatively to these diseases in order to select for combined resistance. Photoperiod and temperature variations during these seasons permit selection for these environmental stresses.

The AVRDC ideotype for mungbean is a monocrop with yield of 3 t/ha at maturity of 70 days (57.1 kg/ha/day) under optimum environmental and cultural conditions. This assumes having 20 pods/plant, 10 seeds per pod, 6 gm per 100 seed, and a plant population density of

250,000 to 400,000 plants/ha. To have sufficient "source", a rapid and vigorous vegetative growth is needed. The characters visualized to attain this goal are rapid seedling growth, dark green lanceolate leaflets, no branching, a strong erect stem, vigorous root system, abundant nodulation, extended photosynthesis, a vegetative/reproductive ratio of 4 : 3, high and efficient photosynthesis, and efficient translocation of the photosynthates. To obtain better distribution of the "sink" would require a high harvest-index with a large number of nodes and short internodes, multiple peduncles at each node with abundant pods per cluster, synchronized flowering and ripening, nonshattering, pods above the seed canopy, large number of seeds per pod, and large seeds. For yield stability, resistance to diseases and insects, tolerance to temperature and moisture stresses, and resistance to seed weathering are needed.

Mungbean yield potential has been more than doubled in breeding lines at AVRDC employing a multidisciplinary breeding approach. Plant architecture is being altered to provide for more pods exposed above the canopy and more synchronous maturity. There is also progress in obtaining less sensitivity to photoperiod and temperature and resistance to multiple diseases.

4. Vegetable Soybean

Introduction, and selection of purelines were major breeding methods used in the development and release of vegetable soybeans. For example, in Taiwan, Tzuzunoko and Ryokkoh were two varieties introduced from Japan. The pod and seed quality, flavor and seed size were primary selection criteria. For Japanese market the characteristics described earlier are the most important characteristics the breeders look for. Selection for 'holding ability', i.e. how long the line can remain in harvestable condition is quite important for the processors.

In Vegetable soybeans the terminal node or the penultimate node or both appear to be without pods. However, the trait is quite variable within the population and it varies with season. Therefore, as a selection criteria it is not a dependable trait.

Pod length and pod width are significantly positively associated with seed size. Therefore, one can select at R_5 stage for the seed size.

If crosses are made between large seeded vegetable types and small or medium seeded grain type in order to derive a vegetable type with large seed through straight inbreeding, it is essential to have very large population size. Even then it is likely that all the desirable characteristics of the vegetable types could not be combined in the selections. Results of such straight cross suggest that at least two to three back crosses to vegetable types following the initial cross is desirable to quickly recover vegetable types with all desirable traits.

Narrow leaflet gene appears to be either tightly linked or it has a pleiotropic effect to produce higher percentage of two and more seeded pods. Therefore, at present attempts are being made to incorporate the narrow leaflet gene (lnln) into the vegetable soybean types since the Japanese market prefers two and three seeded pods. However, when the leaves are narrow, especially with small leaf size, foliage do not fully protect the developing pods. As a result the pods which are exposed to sun develop anthocyanin pigments on the green pod wall which is undesirable for the market. Therefore, large size narrow leaflet type with large leaf area are being selected. Genetic variation is also observed for anthocyanin pigment formation on the pod wall.

Vegetable soybeans are also used like shelled peas; the beans are shelled and marketed either fresh or frozen. The number of seeds per pod is not very critical for such soybeans.

But easy to shell and clean for marketing combined with high yield potential are some important selection criteria. From quality point of view large seed size, bright green color with good appearance, flavor and taste are used for selection. A sample data collection sheet is give in Table 7.

Average graded pod yield, in farmer's field, varies from 3 to 5 t/ha in Taiwan depending upon the season and genotype. The newly improved variety, KS # 1 has an average yield of 3 to 7.5 t/ha in different seasons. In experimental conditions new breeding lines exhibit a potential to produce upto 12 t/ha graded pod yield.

BREEDING ACHIEVEMENTS—SELECTED IMPROVED VARIETIES

1.Snap Bean

For frozen bean, variety Tendercrop released in 1955 in the USA is still used today. In 1970, 46% of the bush type green-podded beans had Tendercrop in their ancestry. The pods of Tendercrop are large, fleshy, bright green, smooth, straight, round and has a slow rate of seed and fiber development (good 'holding ability'). It has concentrated pod maturity.

White seeded Early Gallatin is an excellent canning variety. For fresh market OSU-1640 is an excellent variety. It gives a yield of 20-25 t/ha. Earligreen, Earliwax, Slendergreen, Slimgreen, Improved Tendergreen have been developed by a private company and are quite popular.

Some of the germplasm carrying special traits are listed in Table 8.

Table 8. Germplasm with special characteristics.

Name or No.	Character (s) or (Resistant to)
Tendercrop	Known for its plant type
Blue Lake	known for pod quality
PI 165426	Small leaf size, resistant to rhizoctonia root rot, root-knot nematode
Apollo	Resistant to curly top virus
Blue Mountain	Resistant to curly top virus
Gold Crop	Resistant to curly top virus
Wonder green	Resistant to curly top virus
PR-190	Rust
BARC-1	Rust
8 BP-3	Rust, anthracnose
Resisto	Rust
BBSR-13	Rust, haloblight
BRR-46	Pythium and *Aphanomyces* rot
RRR-36	Pythium and *Aphanomyces* rot
Noorinbee	Haloblight
RH-13	Haloblight
HB-76-1	Haloblight
Epoch	Brown spot
Viva Pink	Highest rate of N_2 fixation
5BP-7	Heat tolerant

Table 7. Vegetable soybean data sheet.

Experiment :　　　　　Vegetable Soybean　　　　　Location :

Note :　　　　　Data Collection Sheet　　　　　Date Sown

F. #	Cross	Pedigree	No. Har.	FPL	Flower		Maturity		Br.	Node	Pod No./5 P			Pod Wt./5P		
					C	Day	Ht.	Day			1S	2S	3S	1S	2S	3S

Lp		WP		Pod No./500g			Yield			SW/ 500 g	100 wt.	Damage Pod		W/Pod or W/o Pod		Lod	Color	Remarks
2S	3S	2S	3S	2S	3S	Total	PW	SPW	TW			Pod No.	Pod Wt.	Top Node	Two Node			

Remarks: 1. FPL=Length from bottom to first pod; 2. C=Color; 3. LP=Length of pod; 4. WP=Pod width ; 5. PW=Pod weight; 6. SPW=Standard pod weight;
7. TW=Total weight (leaf, pod and stem); 8. SW=Seed weight; 9. W/Pod=With pod; 10. W/o pod=without pod.

2. Peas

Round or wrinkled seed coats; yellow and green cotyledon are the key characters distinguishing the varieties. Varieties are also grouped according to plant height (bush or dwarf, medium tall, and tall); according to maturity (early, medium and late), to use of pods (fresh market, freezing, canning and dehydration).

Some of the major cultivars and their characters are given in Table 9.

Table 9. Major pea cultivars and their traits.

Cultivar	Shelling percentage	Use	Others
Alaska	42	Canning	
Early Superb	40	Canning	Dwarf
Meteor	45		
Badger	40	Fresh market, Dehydration	Dwarf
Little Marvel	40	Sweet, fresh market	Dwarf
Bonneville	45		Medium tall
Lincoln	45	Canning	Dwarf to medium tall
Delwiche Commando	45		Medium tall
Thomas Laxton		General purpose freezing	
Sylvia		Edible podded	Tall
Heymuu		For Tender leaves	Branching type
Sugar Snap		For Tender leaves	Branching type

Early Sweet or Alsweet is replacing Alaska. Alsweet has higher yields due to more double pods. Seeds are wrinkled.

In Taiwan recently the edible podded pea is becoming popular.

For tender green leaves, quick growing and easily branching types with crisp tender tips and first leaves are preferred. Heymuu and Sugar Snap varieties meet these qualifications.

3. Mungbean

India has done considerable research on mungbean through their "Pulse Scheme" since 1943. In 1967 an All-India coordinated Pulse Improvement Program commenced. Yield and disease resistance were the primary concerns. A number of varieties have been released (Table 10).

In the Philippines synchronized maturity, seasonal adaptation and high yield along with disease resistance was emphasized. BPI at the Economic Gardens and the University of the Philippines at Los Banos conduct research and release new varieties.

Indonesia, Thailand, U.S.A. , Sri Lanka and Australia have mungbean breeding program and they have released new improved varieties that are high yielding, carrying resistance to powdery mildew, cercospora leaf spot, synchronized maturity and large seed size. A list of varieties released in different countries from AVRDC materials are given in Table 11.

Table 10. Mungbean cultivars released in India.

Cultivar name	Source/ parents	Year	Location	Maturity (days)	Improved characters[1]	References[2]
I. Developed as selections						
Type 1	Muzaffarpur	1948	U.P.	60	G, GM	1
Shining Mung No. 1	Kulu Mung Type 1		Punjab	65	LG, S	2
CO1	Local	1952	Tamilnadu	135	SG, DL	3
CO2	PLS 365/3	1975	Tamilnadu	65	DG	4
CO3	PLS 367	1976	Tamilnadu	70	SG, IRC	4
BR-2	Bhagalpur Local		Bihar	110-115	MG	5
Amrit	Bihar Local		Bihar	90	MY,YMV	5
Khargone-1	K 119-56		M.P.	65	LG, GM	5
R-288-8	Local		Rajasthan	70-75	SG	5
Krishna-11	Gwalior Local		M.P.	65	LG, GM	5
D66-26	Local	1968	Rajasthan	60-65	SG	5
Pusa-Baisakhi	Type 44		New Delhi	60-65	DG, spring and summer	5
Kopergaon	Local	1975	Maharashtra	60	SG	6
II. Developed by hybridization and selection						
Type 44	Type 1 x Type 49	1948	U.P.	60-65	DG, summer, spring	7
Type 51	4465-4 x Type 49	1962	U.P.	75-80	SG, mixed crop	8
Jawahar-45	Madira x UP local	1972	M.P.	75-80	SG,Kharif	9
S-8 (Mohini)	BR 2 x T 2	1972	New Delhi	60-65	SG	10
Kanke Multi-purpose	T1 x China Moong 781	1973		-	SG	11
ML1	Hyb. 45 x p 23-67	1973	Punjab	90	G, tolerant to disease	12
KM 1	S 8 x PS 16	1978	Tamilnadu	65	YMV, pod borer	5
ML5	No. 54 x Hyb. 45		Punjab	80-85	G, Kharif	5
PS 7	-	1981	New Delhi	60-65	DG, summer	5
PS 10	-	1981	New Delhi	60-65	DG, summer	5

[1] G: Green seed; GM: For green manure; LG: Light green seed; SG: Shining green seed; S: Shining seed; DG: Dull seed; DL; Dry land; IRC: Irrigated conditions; MG: Mottled green seed; MY: Mottled yellow; YMV: Yellow mosaic virus tolerant.

[2] 1. S.P. Singh, 1955; 2. S.G. Singh, 1965; 3. Premsekar and Srinivasan, 1961; 4. Rathnaswamy et al., 1977; 5. D.P. Singh, 1982; 6. Mandoli and Nigam, 1966; 7. Pathak and Singh, 1961; 8. Pathak et al., 1962; 9. L. Singh et al., 1972; 10. S.P. Singh, 1972; 11. Bhargava, 1973; 12. S. Singh et al., 1973.

Table 11. AVRDC mungbean selections released as cultivars in different countries.

Cultivar	AVRDC no.	Year of release	Country	Improved characters[1]
ASVEG 78	VC 1089-A	1978	Costa Rica	HY
Bangasa	V 3476	1980	Korea	HY, UM, LR
Tainan Sel. #3	VC 1628A	1981	Taiwan	HY, UM, LR
M 986		1981	India	
	VC 1560D[2]	1982	Australia	
King	V 1388[2]	1982	Australia	HY, EM, PW. LR
Station 46	VC 1000-45-B	1982	Fiji	HY
Seonhwa Nogdu	VC 1973-A	1982	Korea	HY, MMV, RPM, (CLS), UM
Type 77	VC 1131-B-12-2B	1982	Sri Lanka	HY, MYMV, CR
Manyar	VC 1089-A	1983	Indonesia	HY, CLS, R
Nuri	V 2773	1983	Indonesia	HY, (CLS), R
		1983	Malaysia[3]	
Imara	V 1380	1983	Tanzania	
Station 25	VC 1007-14-1-5B[3]	1984	Fiji	
Station 27	VC 1160-1-1-2B[3]	1984	Fiji	
BPI Mg2	VC 1163	1984	Philippines	HY, CLS, RPM, R
Xu Yin No. 1	VC 1973-A	1985	China	HY, WA
Boliche 451	VC 1163[3]	1985	Ecuador	
KPS No. 1	VC 1973-A	1985	Thailand	
KPS No. 2	VC 2778-A	1986	Thailand	
Walet	VC 1163-A	1986	Indonesia	HY, NS, CLS, RPM, TDO, UM
Gelatik	VC 1160-22-2B-1-B	1986	Indonesia	HY, NS, CLS, RPM,UM
BPI Mg4	VC 2764-B	1986	Philippines	HY, UM, LR, EM, (CLS), RPM
DX 102a	VC 2768-A	1986	Vietnam	HY, SLS- R, RLD
DX 113	VC 2763-A	1986	Vietnam	HY, TASS, RLD

[1] HY: High yield; UM: Uniform maturity; LR: Lodging resistant; EM: Early maturing; PW: Resistant to pod weathering; CLS/ (CLS) : Resistant/moderate resistant to *Cercospora* leaf spot; RLD: Resistant to local diseases; SLS-R: Sandy loam soil after rice; TDO: Tolerance to damping off; R: Rust resistant; MMV: Resistant to mungbean mottle virus; RPM: Resistant to powdery mildew; MYMV: Resistant to mungbean yellow mosaic virus; CR: Resistant to charcoal rot; WA: Wide adaptability; TASS: Tolerant to acidic and saline soils; NS: Non-shattering.

[2] Adapted selection developed from AVRDC parental stocks.

[3] Reported release but no further information.

Through intensive research efforts at AVRDC in collaboration with the national program scientists the yield potential of mungbean has been improved from 0.5 t/ha to more than 2 t/ha. Photoperiod insensitivity, multiple disease resistance, large seed size and synchronized maturity have been incorporated in improved lines.

4. Vegetable Soybean

The most popular vegetable soybeans in Japan are predominantly developed by private seed companies. Among 50 new vegetable soybeans, the most popular ones are : Tzuzunoko, Ryokkoh, Kegon, Hatsutaka, Taisho Shiroge, Nakate Kaori, Suzumo, Enrei, Fukuda, Raityo, Shirobato, Tamasudare, Hakutyo, Shiratsuyu, and Blue Side.

In Taiwan at present the leading varieties are Kaohsiung No. 1, Tzuzunoko and Ryokkoh. Kaohsiung No. 1 (KS # 1) is a pure line selection from Taisho Shiroge from Japan done at AVRDC. Detailed trials and final assessment for release was done by Kaohsiung DAIS. KS # 1 was released in 1987. In 1988 it occupied 51% of the total vegetable soybean area in Taiwan. In 1989, it is expected to occupy more than 80% of the area.

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